

SCIENCE FOR CERAMIC PRODUCTION

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POROUS PERMEABLE CERAMICS BASED ON ALUMINUM OXIDE

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The effect of additives (within limits of 15 – 30%) of disperse alumina with different content (up to 2.3%) of TiO_2 and MgO on properties of porous permeable materials based on electromelted corundum of different degrees of dispersion is investigated. Porous ceramics with open porosity up to 40% and bending strength up to 25 MPa is obtained, which has high filtration efficiency and chemical stability.

At present, there are permeable ceramic materials, whose porosity, gas permeability, and other characteristics are adjustable within wide limits. Their chemical, structural, and thermal stability in liquid and gaseous media makes it possible to apply such materials in various areas. The applicability of porous ceramic products for practical use depends on their properties.

Volume filter elements are the main products of permeable ceramics. Ceramic filters provide for a required degree of filtration and can withstand strenuous regeneration conditions. One of the main characteristics of porous ceramics is their permeability, which is determined by the structure of the material. Permeability can be controlled through porosity and pore sizes; however, these possibilities are not the same. A commonly used method of making ceramic filters consists of molding ceramic mixtures consisting of a filler mixed with a disperse binder.

The purpose of the present study to produce alumina-based ceramic material for filters and membrane substrates with high open porosity and a narrow pore-size distribution.

The main physicochemical properties of ceramics are formed at the stage of thermal treatment, which makes a significant contribution to the cost of a finished product. It is known that the structure of porous ceramics mainly depends on the packing of filler particles and their adhesion via binder in the sites of contact. It is preferable to control such important physicochemical characteristics of filters as permeability and filtration fineness by selecting a size of the filler grains and also by selecting the type and content of the highly disperse component (binder). The mechanical strength of filtering ceramics is determined by strength of adhesion

on the site of contact between the filler particles and the binder and by the strength of the binder itself [1].

Electromelted corundum powder M20, M40, M63, and No. 10, which contain particles close in size, were used to develop a porous structure in material.

The binder ought to be highly dispersed and uniformly distributed between filler particles. At the same time, its content should be minimum, since the binder decreases porosity. The use of argillaceous binders makes it possible to obtain materials of strength up to 10 – 12 MPa at a firing temperature of 1200 – 1300°C. However, the presence of argillaceous components leads to the formation of a vitreous phase and, consequently, decreases chemical resistance. Accordingly, it was decided to use alumina of grade GLMK with magnesium dioxide and titanium dioxide additives as the highly disperse component. After it was fired at a temperature of 1550°C, a sintered material with bending strength up to 300 MPa was obtained [2].

Petrographic studies of the initial powder of the highly disperse component indicated that the size of the GLMK particles is 1 – 2 μm and occasional particles are 3 – 4 μm . Magnesium oxide and titanium dioxide particles are uniformly distributed and have a size up to 1 μm . Adsorption of oxide particles on the surface of GLMK particles is observed.

The microstructure and properties of the material obtained from the highly disperse component with different contents of MgO and TiO_2 were studied. As the additive content increases, the density and strength of samples grow (firing temperature 1500°C). Petrographic analysis indicated that the material consists of corundum crystals sized 2 – 5 μm with a nearly isometric shape. Aluminomagnesia spinel with crystals sized up to 1 μm is located at the edges.

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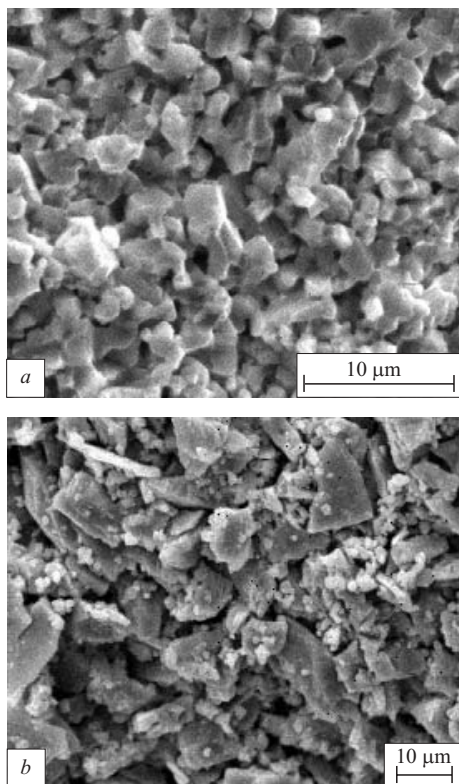


Fig. 1. Microstructure of sample from alumina GLMK with MgO and TiO₂ (a) and sample based on electromelted corundum M20 (b).

A phase of magnesium titanates with crystals up to 2 μm becomes crystallized at the periphery and envelops the corundum crystals. Sealed intercrystalline porosity does not exceed 0.5%. An increase in the content of MgO and TiO₂ up to 3% leads to larger corundum crystals. The presence of free titanium oxide is registered as well. The material structure is shown in Fig. 1a.

To identify an optimum quantity of binder, mixtures based on electromelted corundum were prepared with different contents of the highly disperse component (5, 10, 15, and 20% for corundum M20 and M40 and 15, 20, 25, and 30% for corundum M63 and No. 10). Samples were molded by semidry molding, dried, and fired at a temperature of 1350–1500°C. Fired samples had porosity up to 40% and permeability up to 0.23 μm². A decrease in strength was registered with a growing size of the filler grains under a constant content of the highly dispersed component. This can be attributed to a decreasing specific surface area of the grain and, accordingly, a decreasing surface area of contact between the sintering additive and filler grains. Structural analysis carried out with an electron microscope indicated that the highly dispersed component is uniformly distributed between the filler grains. The average pore size of the material based on electromelted corundum M20 is around 2.0 μm

TABLE 1

Mixture	Porosity, %	Bending strength, MPa	Efficiency of capturing model particles, %	Permeability coefficient, μm ²
M20 + 20% binder	38.0	26.3	> 99.9999	0.05
M40 + 20% binder	37.0	13.3	> 99.9999	0.09
M60 + 30% binder	32.7	18.2	99.9964	0.06
No. 10 + 30% binder	29.1	12.4	99.9091	0.23
M20 + 20% binder + 15% (NH ₄) ₂ CO ₃	49.3	12.3	> 99.9999	0.12

(Fig. 1b). The alkali resistance of this material, which had the highest porosity and strength, was equal to 99.7%. Alkali resistance was determined by holding samples in a 35% solution of sodium hydroxide for 8 h at a temperature of 80°C.

An efficient method for increasing open porosity of materials is introduction of additives that completely decompose in firing [3]. To modify the material, 15 wt.% ammonium carbonate was added to a mixture based on electromelted corundum M20 with a 20% sintering additive containing 3.0% MgO and TiO₂. After removal of ammonium carbonate crystals, large pores (up to 50 μm) are formed. The porosity of the sample in this case grows significantly.

To determine filtrating parameters of the materials obtained, they were tested with respect to gas-dynamic resistance and efficiency of air purification from turbine oil particles of diameter 0.25–0.30 μm (Table 1). It can be noted that the use of pore-forming additives increases the gas permeability of the material, whereas the purification effect is not diminished.

Thus, the use of electromelted corundum with particles sized 20–30 μm as a filler and disperse alumina GLMK with MgO and TiO₂ as a binder makes it possible to obtain materials with a porosity of 38%, strength up to 25 MPa, and a chemical resistance not less than 99.7%. The use of pore-forming additives makes it possible to raise the porosity of material up to 49%, in which case gas permeability significantly grows.

The developed materials hold promise for industrial production of chemically resistant permeable elements.

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